Measuring Cognitive Workload in Non-military Scenarios Criteria for Sensor Technologies

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Abstract. Augmented Cognition manifesting in the DARPA project is becoming of more and more interest to non-military application areas. First areas it is going to be applied are in flight control and power plant control. Measuring cognitive workload in the context of Augmented Cognition is bound to the application of sensor technologies and frameworks which are going to be applied to users. It is necessary to make Augmented Cognition Application in non-military areas as comfortable to the user as possible as we do not want to disturb her but to support her in her tasks. In this paper we will define criteria to be considered when designing Augmented Cognition applications in non-military environments.

Keywords: Augmented Cognition, Application, Sensors systems, sensor chriteria.

1 Introduction and Objective

Augmented Cognition is becoming more and more of interest to non-military application areas. First areas it is going to be applied are flight control centers, power plant control centers or simulation centers. Extending this thought one might think of other control scenarios where users and computer have to work collaboratively together, where tasks are to be carried both by men and machine, one supporing the other.

As Schmorrow and Kruse discussed "Augmented Cognition distinguished from its predecessors by the focus on the real-time feedback cognitive state of the user, as assessed through modern neuro-scientific tools." [1] Systems developed by using Task-Centered Design need to monitor both information flow as well as the cognitive state of the user to meet the objectives they are designed for [2].

This shortly leads to the application of Augmented Cognition in everyday life scenarios like buying train tickets at ticket machines, ATM usage, or writing articles, email and reports, programming new software or doing technology supported workplace learning [3]. As people in todays business life do not work on one task only at a time but many tasks simultaneously support is needed [4].

We are aiming at introducing Augmented Cognition technologies into different application areas and are looking for sensor types which can be used to recognize

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the users cognitive workload in a way the user would accept and provide the computer with the information it needs to support the user as best as possible. So the objective of the research presented here is to find criteria for sensor types in the respective environments and tasks acceptable by the users in their distinguished situations.

2 Measuares for of Cognitive Workload

As in military applications both "high demand" and "vigilance" scenarios are to be supported in adaptive automation application [5]. Application shall support users in their task work by optimizing her workload for optimal performance [6,7,8].

As measuring cognitive workload unfortunately is not possible directly, we have to use tools to recognize the humans load. There are different methods For measuring cognitive workload mostly applicable in laboratory environments. First subjective workload measures like Cooper-Harper-Scale [9], NASA task load index [10] or Subjective Workload Assessment Technique [11] and performance-based measures [12,13] have been proposed. Later estimation methods using psychophysiological parameter and body observations (e.g. Index of cognitive activity [14]) which would support the criteria on in-time estimation were developed. We focus on the estimation of cognitive workload by analyzing psychophysiological parameters and other data acquirable by sensors from the user.

3 Criteria for Sensor Technologies

Depending on the application area different criteria have to be met by the sensors. As they are the basis for Augmented Cognition applications they need to be accepted by the operators themselves [15,12]. Therefor the sensors need to be:

non-intrusive. Users will not carry implants or needles or other devices which may hurt them in any way [16].

non-obtrusive. The applied sensors do not disturb the handling of the user during the tasks performance.

easily applicable. The sensors are easily applicable to the user or work in remote sensing way, so would n't take much effort to start gathering data.

In technological terms sensors need to be usable for calculating estimates of the cognitive workload of the user. Technologically sensors should provide adequate data precision, should have an adequate data rate, and should be easily combinable with other sensors. Technological requirements are:

adequate precision. Sensors should be able to deliver data in a quality high enough to calculate estimates of the users cognitive workload.

adequate data rate. Data rate and transmission rate from sensors should be adequate to calculate estimates of cognitive workload.

combinability. Sensors support industrial and other standards, which allow them in any combination and connect them easily to a data transmission and collection framework [17,18].

Those criteria apply to all technical components, meaning sensors as well as data transmission components and computers necessary for cognitive workload estimation. When designing user friendly systems and applications those criteria should be taken into consideration. It is recommended to apply methods of human-centered and task-centered design [2].

Furthermore the factors sensitivity, diagnosticity, primary task intrusion, implementation requirements and selectivity should be taken care of [15,12]. An overview of sensor types vs. sensitity, obtrusiveness, avalibilty is given in [19].

4 Sensor Types and Classification

Science reports on research attempting to connect workload indices to one psychophysiological parameter. Unfortunately the

> "...indirect nature of derived psychophysiological parameters prevents a straightforward interpretation concerning the functional aspects of the human organic system..." [20]

– as it prevents from directly concluding from measured signals to cognitive workload. The main reason is that there is not a direct physical or physiological connection as the measured psychophysiological parameters finally just are reactions of the human brain and body on external and internal exposure and their resulting workload. Therefore it is absolutely necessary to receive high quality data of the measured psychophysiological signals. Advises on ensuring high quality signal data can be found in the references (e.g. [20]).

Estimates of the current cognitive workload can be calculated using combinations of measurements of different sensor types. When following up those criteria we may classify different sensor types in respect to their usability in new application areas and their acceptance by users. Different sensor types may be used and combined to acquire information on the users cognitive workload [21,12]. This approach works well in the field of emotion recognition [22] and accounts for measuring cognitive workload, as well. The following sensors have been proved to support reognition of cognitive workload:

- Electroencephalography (EEG), Magnetoencephalography (MEG) [23,24]
- Functional Near Infrared Neuroimaging (FNIR) [25,26]
- Pupil diameter using eye tracker [27,28,29,2,14,30,31,32]
- Psycho-physiological sensors like galvanic skin respondance, heart rate, blood pressure [23,33,34,35]
- Eye blink [30,28,36,34,8,37,27,32]
- Facial skin temperature [38,30]

– Other sensors types including selfmonitoring methods [39]
– Ad hoc wireless Body area network [17]

Sensors and technologies used to estimated users emotions might be applicable as well like for example facial play or voice and speech anaylysis [40,41].

Table 1 shows the sensor types and their respective criteria quality.

Table 1. Overview over sensortypes in respect to criteria

Sensor name	*sensor type*	*non-intrusive*	*non-obtrusive*	*easily applicable*	*adequate precision*	*adequate data rate*	*combinability*
EEG / MEG	directly connected to body	−−	−−	−	○	+	+
Near infrared	directly connected to body	−−	−−	−	○	+	+
Pupil diameter	remote sensor	++	+	○	−	−	+
Psycho-physiology	directly connected to body	−−	−−	−	○	+	+
Eye blink	remote sensor	++	+	○	−	−	+
Facial skin temperature	remote sensor	++	+	○	−	−	○

Looking at those criteria one finds out that remotely working sensors which automatically track the user during her task performance are in favor to the user acceptance criteria, whereas the sensors directly connected to the users body deliver the necessary data quality and data rate. All sensor types can be combined when using data wrapping technologies.

5 Conclusion, Outlook

We focus at applying Augmented Cognition in new application areas like Interactive electronic technical documentation[1], adaptive electronic tutorials and learning materials as well as adaptive user interfaces. User-centered technologies appraising cognitive workload will be accepted by the user if the sensing part is acceptable. As we showed those sensors have to be remotely operational, non-intrusive and non-obtrusive. Therefor more effort has to be spend on new and further development of tracking technologies remotely working. One new technology could for example include the users activity in the estimation of cognitive workload [42].

One key criterium to be considered furthermore in prospective investigations is the users privacy. Being able to track a users cognitive workload remotely may conflict with her idea of privacy.

[1] IETM – Interactive Electronic Technical Manual, for explanation see `http://en.wikipedia.org/wiki/IETM` or `http://www.cpt.fsu.edu/pdf/ietm1.pdf`

Even though the research area Augmented Cognition is still looking for its “killer app” [4], it is leaving the military sector and extends to application areas in every day life. In this paper we discussed the use and the combination of different sensor types for capturing user data relevant to her cognitive workload. We proposed several criteria which might be useful to select sensor types for new applications of Augmented Cognition.

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